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ABSTRACT

One of the concerns with the proposed large space-power systems operating at high voltages is the interactions with the space charged-particle environments. These interactions can influence the performance of space power systems and should be evaluated and minimized early in design phases. An analytical tool that can be utilized to study these interactions exists. It is called NASCAP, an acronym standing for NASA Charging Analyzer Program.

In this report the initial application to large, high-voltage space power systems is presented. A simple space power system operating in geosynchronous orbit is analyzed. This system consists of two solar array wings, each 6 m by 18 m, surrounding a central body 6×6×3 m. Each solar array wing is considered to be divided into 3 regions operating at 2000 volts. The center body is considered to be electrical ground with the array voltages both positive and negative relative to ground (±6 kV maximum). This system is analyzed for both a normal environment and for a moderate geomagnetic substorm environment.

These initial results indicate a high probability of arcing at the interconnects on the negative operating voltage wing. There is also the possibility that the dielectric strength of the substrate can be exceeded (if the operating voltages are increased) giving rise to breakdown in the bulk of the material. The geomagnetic substorm does not seem to increase the electrical gradients at the interconnects on the negative operating voltage wing but does increase the gradients on the positive operating voltage wing which could result in increased coupling current losses.

E-001

INTRODUCTION

Very large space power systems are being proposed for future applications. These systems are to be used for such diverse activities as manufacturing, technology demonstrations, communications and receiving power for Earth usage (refs. 1 to 6). These systems are proposed for operations in orbits ranging from low Earth orbits (200 to 400 km) to geosynchronous. The power levels extend from 25 kW power modules (ref. 7) to multikilowatt power systems (ref. 8) to the gigawatt output of the Solar Power Satellite (SPS) (refs. 4 and 5). Since the power level is proportional to the surface area, these systems will be large with dimensions from 10's to 1000's of meters.

It will be necessary for these systems to operate at elevated voltages to reduce line loss and minimize system weight (ref. 9). For these reasons the SPS is designed to generate 15 gigawatts at 40 kV (refs. 4 and 5). At voltages in the kilovolt range, interactions with the charged particle environment are possible. There has been limited experience with high voltage power systems operating in space environments. In fact, the highest operating voltage used to date is the 100 volt system on Skylab (ref. 10). So, the extension from this level, interactions should be negligible, to higher voltage levels should be approached cautiously.

In this report the background information on charged-particle interactions is briefly reviewed. An analytical model of a high voltage space power system is developed in the NASA Charging Analyzer Program (NASCAP) computer code. The possible interactions between this system and the geosynchronous orbit environment are analyzed for possible impact on system performance.

CHARGED PARTICLE INTERACTIONS WITH HIGH VOLTAGE SYSTEMS

In this section a summary of possible interactions with the charged particle environment that could influence system performance will be given. To illustrate the type of systems proposed for future applications, consider the system shown in figure 1 (ref. 8). This system is a space construction platform with a 250-kW solar array attached, to provide power for space construction operations and technology demonstrations. Note the relative size of the Shuttle orbiter compared to the structure. Similar large power systems are proposed for geosynchronous orbits.

These large space power systems must operate in a charged-particle environment that is quite complex (see figs. 2(a) and (b)). There is a thermal plasma in which the particles have energies of 2 eV or less (ref. 14). This thermal-plasma environment has a maximum density of 10^6 particles cm^{-3} at 300 km and falls off to about 1 particle cm^{-3} at geosynchronous altitude (see fig. 2(b)).

The Earth's magnetic field influences the charged-particle environment. It generates the radiation belts in which both high energy electron and protons can bombard a spacecraft. At geosynchronous altitudes, this field can accelerate solar storm particles to kilovolt energies creating a condition called "geomagnetic substorm" which are believed to cause spacecraft charging anomalies (refs. 11 to 13).

A body immersed in a charged-particle environment will assume voltages such that particle currents incident on the body from the environment equal particle currents leaving the body so that the net current is zero. Under normal environmental conditions, the electron current incident on the surfaces will be balanced by the proton current, the photoemitted current (from sunlit surfaces), the secondary emission currents (from both proton and electron impact) and the backscattered currents. If there is a change in any of these currents, such as the cut-off of photocurrents by shadowing, then the surface voltage will adjust to inhibit electron flow and maintain current equilibrium. Hence, it is possible for differential charging to build up on shadowed insulators relative to the sunlit spacecraft structure.

In geosynchronous satellites the geomagnetic substorm condition can enhance this differential charging (see fig. 3). The substorm adds an additional flux of kilovolt particles having a current density of about 10^{-9} A/cm^2. This overwhelms the other currents and can cause the sunlit ground surface to assume a voltage of 100's of volts negative while shadowed insulators are driven to 1000's of volts negative. This differential voltage can exceed breakdowns and the resulting transient can cause electronic switching anomalies.

The above interactions apply to all satellites. When a high voltage space power system is utilized, then additional current collection phenomena occur. Such a high voltage space power system (having exposed, biased conductive surfaces) is illustrated in figure 4. In the standard construction of a solar array, cover slides do not completely cover the metallic interconnects between solar cells. These cell interconnects are at various voltages depending on their location in the array circuits. Because the array is exposed to space plasmas, the interconnects act as biased plasma probes attracting or repelling charged particles. At some location on the array the generated voltage is equal to the space plasma potential. Cell interconnects that are at voltages above the space potential will attract an electron current while those that are below the space plasma potential will repel electrons and atract an ion current. The voltage distribution in the interconnects relative to space must be such that these electron and ion currents are equal. This flow of particles can be considered a current loop through the power system to space which

can be a loss in the power system. Since proposed operating voltages are only in the kilovolt range, the electric fields generated in the space plasma by the exposed interconnects can only attract or repel the lower energy plasma particles. The very high energy particles (>keV) will not be influenced by the spacecraft system generated fields. Hence, the thermal-plasma environment will be the one of concern for these interactions. Ground testing with bias voltages applied to relatively small samples has indicated that there can be relatively severe interactions (refs. 15 to 17).

In this evaluation, a large, high voltage space power system operating in both a normal and substorm geosynchronous environment is used. Operating voltages are distributed along the solar array. The specific concerns are the possible plasma currents and the voltage gradients. The model of this system is set up in the NASCAP code as described in the next section.

NASCAP MODEL

Description of NASCAP

Introduction. - The NASA Charging Analyzer Program (NASCAP) has been developed as an engineering tool to determine the environmental impact on spacecraft surfaces and systems. It is capable of analyzing the charging of a 3-dimensional, complex body as a function of time and system generated voltages for given space environmental conditions. The material properties of the surfaces are included in the computations. The surface potentials, low energy sheath, potential distribution in space and particle trajectories are calculated.

NASCAP is a quasi-static computational program, i.e., it assumes that currents are functions of environmental parameters, electrostatic potentials and magnetostatic fields while not dependent on electrodynamic effects. This is reasonable since charging times in insulators are long compared to the computing interval. The following paragraphs briefly discuss the elements of NASCAP. Detailed descriptions, including a User's Manual, are available (refs. 18 to 20). NASCAP is written in FORTRAN V and currently is operational on UNIVAC 1100 and CDC 6600 computers.

Overview. - A flow diagram of NASCAP is shown in figures 5(a) and (b). The logic has been designed to provide maximum flexibility to the user. As execution progresses, the user may request a charging simulation or any of several auxiliary functions such as object definition or particle detector simulation. NASCAP contains full restart capability.

A charging simulation consists of first calculating (for a given environment and surface charge state) the currents incident upon and emitted from the spacecraft surface. From these currents the new electrostatic potentials on the spacecraft surface and in the surrounding space are computed. The process continues for a user specified period of time. The charging simulation may be run such that all currents are considered constant in a specified interval or time step (explicit) or that current variations during the timestep are anticipated (longtimestep option). The charging simulation takes into account such effects as internal bias voltages, Debye screening, and charged-particle emitters.

Computational space. - NASCAP computations are performed in an embedded set of cubic grids of dimension $17\times17\times n$ where $n \leq 33$ (see fig. 6). The object is described in the innermost grid. Each successive outer grid has twice the linear dimension of the next inner one. This allows treatment of a large volume of space while minimizing computation time and storage requirements.

Environment definition. - NASCAP allows specification of the charged-particle environment in a number of ways. Most commonly used are the Maxwellian and double Maxwellian descriptions of geomagnetic substorm environments (ref. 21) which allow independent specifications of temperatures and densities of both the electron and ion components. Provision is also made for nonanalytic specification of the space environment using actual ATS-5 data. A laboratory simulation environmental flux of electrons with a specified beam profile and accelerating voltage can also be used.

Object definition. - NASCAP requires that an object be defined in terms of rectangular parallelepipeds or sections of parallelepipeds. Only thin booms may extend beyond the innermost grid boundary. This object definition protocol allows rather complex spacecraft models to be defined using fairly simple inputs.

Since a spacecraft can be a complex shape and errors in describing the model in terms of the program limitations can arise, a graphical output of the spacecraft model can be generated by the computer to verify the accuracy of the model prior to the start of the computations. Any set of axes or rotation angle can be specified for viewing the object. The computer will also remove all hidden lines. Therefore, it is possible to obtain 3-dimensional picture of the object or projections in specified planes. As an example of the graphical output, the NASCAP model of the ATS-6 is shown in figure 7. This model has been generated within the inner grid limitation of $17\times17\times33$ points using sections of parallelepipeds. It is recognizable.

The graphical object definition output will identify the specified surface materials of each cell. Hence, it is possible to determine that the computer model is the desired representation of the spacecraft prior to running the computational portions of the program.

Material properties. - NASCAP allows surfaces to be bare or covered with thin ($\sim 10^{-4}$ m) dielectric materials. Values for properties of common spacecraft materials (e.g., aluminum, magnesium, teflon, kapton, and silica) are supplied. For other materials, properties can be easily added to the code. The properties to be specified include dielectric constant, material thickness, conductivities, backscatter and secondary coefficients (for both electron and ion impact), photoemission and breakdown characteristics.

Electrical connectivity. - In NASCAP the spacecraft model can be composed of up to seven separate conductors. These conductors may be capacitively coupled and may be allowed to float, held at fixed potentials or biased relative to one another. In the latter case, NASCAP automatically transports charge from one conductor to another so as to maintain the bias voltages.

Mathematical algorithm. - NASCAP uses an Incomplete Cholesky Conjugate Gradient (ICCG) algorithm (ref. 18) to calculate the change in spacecraft potential at each timestep ($\sim 10^3$ variables). The spacecraft equivalent circuit used in this calculation is set up by geometrical analysis within NASCAP. The potential in the external space ($\sim 10^4$ to 10^5 variables) is calculated by a finite element, Scaled Conjugate Gradient technique (SCG)(ref. 18). Both potential solvers are capable of handling mixtures of fixed potential and fixed charge boundary conditions at the spacecraft surface.

Output. - In addition to its standard printed output, NASCAP provides an extensive menu of graphical outputs and printed data compilations. Graphical output includes the material and perspective object definition pictures, potential contour plots and particle trajectory plots. The standard printed output includes a summary of all cell voltages, listing of currents to specified surface cells and compilation of electrical stress through insulators listed in decreasing order.

Sufficient information is stored in external files to allow a restart of NASCAP for further analysis, for evaluation under changed environmental conditions or for post-processing analysis with user written programs.

NASCAP High Voltage System Model

The model of the high voltage system considered in this report is shown in figure 8. It consists of two solar array wings with a central body. This choice was arbitrary and is not intended to represent any specific system.

Each solar array wing is 6×18 m and could generate 10.5 kilowatts of power. The solar array is considered to consist of six 6×6 m sections each operating at 2 kV.

The electrical circuit for the array is assumed to be such that the center body of the spacecraft is the electrical ground and each section is in series. Hence, the array sections in one wing are at +2, +4, and +6 kV while the other wing is at -2, -4, and -6 kV relative to the spacecraft body. The cover slides are assumed to be quartz, 0.015 cm thick (6 mils), while the sides and back of the array are covered with 0.010 cm thick Kapton. Since NASCAP can not treat small gaps, the exposed interconnects on the array are lumped as an exposed aluminum area, 1.5 m × 1.5 m, in each section of the array. This amounts to about 6 percent exposed area which is a reasonable approximation to the actual interconnect areas. The apparent thickness of the array is mandated by the version of NASCAP used which required that all dimensions be at least one grid unit. Since there are no serious effects due to the wing thickness anticipated, this simulation is still expected to give valid results. Future versions of the code will allow treatment of thin plates.

The center body is 6×6×3 m. Two of the 6×3 m surfaces have exposed areas of aluminum (3×3 m) while the rest of the body is covered with 0.010 cm thick Kapton.

Voltage profiles around this high power system were computed for two different charged-particle environments:

1. Normal environment - electrons and ions with a density of 1 cm^{-3} and temperatures of 1 eV.

2. Moderate substorm environment - electrons and ions with a density of 10 cm^{-3} and temperatures of 5 keV.

In both cases sunlight was normally incident upon the solar array. The results are discussed in the following sections of the report.

DISCUSSION OF RESULTS

Normal Environment

The equilibrium voltage distribution around the high power system in the normal geosynchronous environment is shown in figure 9. The two views shown are: a side view in the plane of the solar array and a top view from a position normal to the plane of the array.

Current collection due to the operating voltages on the solar array drive the central body potential to -180 volts relative to the space plasma potential. The result is that the voltage distribution around the negative-voltage wing is enhanced while the voltage distributions around the positive-voltage wing is restricted concen-

trating the gradients at the simulated interconnects. The total electron current collected is equal to the ion current as required. The value of this plasma collection current is negligible compared to the power system operating currents.

The detailed voltage distributions on the array are shown in figure 10. In this figure the voltages of the central body and the six sections of the array are shown. Note that the Kapton surface voltage on the back of the array always remains considerably less than the conductor voltage. The electric field through this 0.010 cm thick layer can be a maximum of 5×10^5 volts/cm. If this condition holds for higher operating voltages then it is conceivable that the dielectric strength of the substrate could be exceeded and breakdowns could occur. This would produce transients on the power bus.

On the quartz side of the array the conductor voltage is concentrated at the simulated interconnects. The electric fields do grow into the quartz regions but the voltages in these regions remain small compared to the various conductor voltages.

The voltage profile across the surface of the solar array is shown in figure 11. This profile does show the severity of the gradients at the interconnects. On the negative-voltage wing the gradients are becoming severe enough to induce edge breakdowns similar to those that occur in spacecraft charging interactions (ref. 22). Arcing to and from the power circuit would induce transients that could produce power interruptions. There are also strong gradients existing on the positive-voltage wing. However, experimental evidence indicates that these gradients do not cause detrimental interactions (ref. 17). The predicted behavior for the positive-voltage wing does not match exactly the small sample laboratory data in that the interconnect voltage should have encompassed the quartz. The lack of agreement here could be due to a plasma sheath phenomena which has not been included in this model.

Substorm Environment

Since this power system must operate in geosynchronous orbit, the effects of geomagnetic substorm interactions must be evaluated. The high voltage system model was exposed to a moderate substorm condition (fluxes of 5 keV electrons and ions) and the resulting voltage distributions computed. The voltage distributions around the high power system for this condition is shown in figure 12. Again this figure shows a view from a position normal to the plane of the array and an edge view through the array. In this case the spacecraft body potential is depressed to -2400 volts relative to the space plasma potential. This results in negative voltages

in the space around the entire system with positive voltages being confined to the simulated interconnect regions.

A more detailed view of these voltage distributions is shown in figure 13. This figure shows the distribution for the Kapton beneath the array, the edge view through the array and the solar cells. The Kapton surface, which is shadowed, tends to come into equilibrium with the environment at about -3400 volts. The front of the solar array must come into equilibrium under the photoemission, the substorm fluxes and the attractive fluxes due to the operating voltages. This results in the depression of the spacecraft body potentials and voltage concentrations at the simulated interconnects. The electric fields in the Kapton substrate may exceed the dielectric strength of the material leading to breakdowns in the previous case.

The surface voltage profile across the array illustrates the interconnect voltage concentration (see fig. 14). Comparison of these voltage distributions with the ones under normal environment (fig. 11) shows that while the negative-voltage wing gradients are about the same, the positive wing gradients have increased. Even with the increased gradients, however, the current collected through the plasma still remains negligible compared to the operating currents.

The effect of substorm, then, is to depress the spacecraft ground potential relative to the space plasma potential. In addition, the insulating substrate can be driven to a more negative potential giving rise to concern over possible breakdown through the substrate. While the substorm environment does not appear to enhance the possibility of arcing at the interconnects, it does not alleviate this arcing possibility.

CONCLUDING REMARKS

Future space power systems will be required to generate large amounts of power ranging from multikilowatts to gigawatts. These large systems must operate at high voltages in order to reduce line losses and system weight. The use of high voltages on systems that must function in the space charged-particle environment requires that possible detrimental interactions between the system and the environment be be controlled.

In this report, the NASA Charging Analyzer Program (NASCAP) computer code is used to conduct a preliminary evaluation of the behavior of a conceptual high voltage system operating in geosynchronous orbit. This system is assumed to have solar arrays operating in 2000 volt increments and connected such that the total operating voltage across the array is 12 kV (±6 kV). A center body is maintained as the system ground.

In a normal geosynchronous environment (~1 eV particles), the operating voltages in the solar array drives the central body to about -180 volts. High voltages are confined to the exposed interconnect regions giving rise to high, localized electric fields. This concentration of electric fields gives rise to the possibility of arcing in the negative portions of the array. Also, the Kapton substrate on the array wings appears to remain closer to space plasma potential than to the operating voltages giving rise to the possibility of bulk breakdown through the insulator. These effects can be quite serious for systems operating at higher voltages than those considered here.

In a moderate geomagnetic substorm environment (~5 keV particles), the central body voltage is driven to -2400 volts. Under these conditions the operating voltages remain confined to the interconnect regions. The resulting gradients at the negative-voltage wing interconnects remain the same as in the normal environment. The gradients on the positive-voltage wing interconnects increase. The Kapton substrate voltage is about -3400 volts which increases the electric field in positive wing substrate and reduces the electric field in the negative wing. Hence, substorm environments appear to drive the system ground more negative, increasing gradients at the interconnects and electric fields in the substrate in the positive voltage wings. The concern remains for the possible arcing at the negative voltage interconnects and breakdown through the substrate.

In both environments the parasitic currents collected through the environment have been computed. These currents are small compared to the operating current of the array. Hence, power losses in geosynchronous environments do not appear to be serious.

This study must be considered to be a first attempt at evaluating high voltage system interaction. It has shown that there are areas of concern for the operation of high voltage systems in space. Additional work is required to incorporate plasma sheath phenomena in the code and to verify that the material properties in the code are correct.

REFERENCES

1. "Outlook for Space", NASA SP-386, 1976.

2. R. D. Johnson and C. Holbrow, eds., "Space Settlements, A Design Study", NASA SP-413, 1977.

3. G. R. Woodcock, "Solar Satellites, Space Key to Our Future", Astronautics and Aeronautics, Vol. 15, pp. 30-43, July-August 1977.

4. "Satellite Power System (SPS) Feasibility Study", Rockwell International Corp., Downey, Calif., SD76-SA-0239-1, 1976. (NASA CR-150439.)

5. "Systems Definition of Space-Based Power Conversion System", Boeing Aerospace Co., Seattle, WA, D180-20309-1, 1977. (NASA CR-150209.)

6. Ivan Bekey, "Big COMSATS for Big Jobs at Low User Costs", Astronautics and Aeronautics, Vol. 17, pp. 42-56, February 1979.

7. Mordan, G. W., "The 25 kW Power Module - The First Step Beyond the Baseline STS", AIAA Paper 78-1693, September 1978.

8. M. Savage and J. W. Haughey, "Overview of Office of Space Transportation Systems Future Planning", in Future Orbital Power Systems Technology Requirements, NASA CP-2058, 1978, pp. 71-92.

9. N. John Stevens, "Interactions between Spacecraft and the Charged-Particle Environment," Spacecraft Charging Technology - 1978, NASA CP-2071, 1979.

10. A. P. Woosley, O. B. Smith, and H. W. Nassen., "Skylab Technology Electrical Power System," AAS Paper 74-129, August 1974.

11. S. E. DeForest, "Spacecraft Charging at Synchronous Orbit", J. Geophys. Rev., Vol. 77, pp. 651-659, February 1972.

12. A. Rosen, ed., "Spacecraft Charging by Magnetospheric Plasmas", Progress in Astronautics and Aeronautics, Vol. 47, New York: AIAA, Inc. 1976.

13. C. P. Pike and R. R. Lovell, eds., "Proceedings of the Spacecraft Charging Technology Conference," U. S. Air Force Geophysical Laboratory Rep. TR-0051 and NASA TM X-73537, 1977.

14. W. F. Springgate and H. Oman, "High Voltage Solar Array Study," Boeing Aerospace Co., Seattle, Wash., D2-121734-1, 1969. (NASA CR-72674.)

15. K. L. Kennerud, "High Voltage Solar Array Experiments", Boeing Aerospace Co., Seattle, Wash., 1974. (NASA CR-121280.)

16. S. Domitz and N. T. Grier, "The Interaction of Spacecraft High Voltage Power Systems with the Space Plasma Environment", in Power Electronics Specialists Conference, New York: IEEE Inc., 1974, pp. 62-69.

17. N. John Stevens, F. D. Berkopec, C. K. Purvis, N. T. Grier, and J. V. Staskus, "Investigation of High Voltage Spacecraft Systems Interactions with Plasma Environments", AIAA Paper 78-672, April 1978.

18. I. Katz, J. J. Cassidy, M. J. Mandell, G. W. Schnedlle, P. G. Stein, and J. C. Roche, "The Capabilities of the NASA Charging Analyzer Program", Spacecraft Charging Technology - 1978, NASA CP-2071, 1979.

19. I. Katz, D. E. Parks, M. J. Mandell, J. M. Harvey, D. H. Brownell, Jr., S. S. Wang, and M. Rotenberg, "A Three-Dimensional Dynamic Study of Electrostatic Charging in Materials," Systems Science and Software, La Jolla, Calif., 1977. (NASA CR-135256.)

20. M. J. Mandell, J. M. Harvey, and I. Katz, "NASCAP User's Manual", Systems Science and Software, La Jolla, Calif., 1977. (NASA CR-135259.)

21. H. B. Garrett, "Modeling of the Geosynchronous Plasma Environment," Spacecraft Charging Technology - 1978, NASA CP-2071, 1979.

22. N. John Stevens, C. K. Purvis, and J. V. Staskus, "Insulator Edge Voltage Gradient Effects in Spacecraft Charging Phenomena," IEEE Transactions on Nuclear Science, Vol. NS-25, pp. 1304-1312, December 1978.

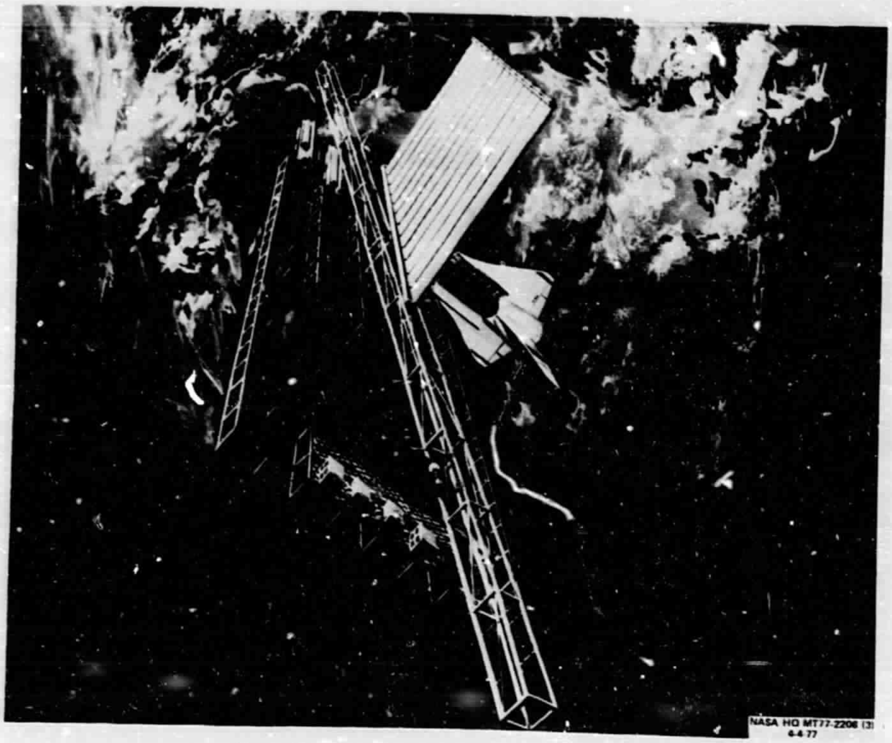
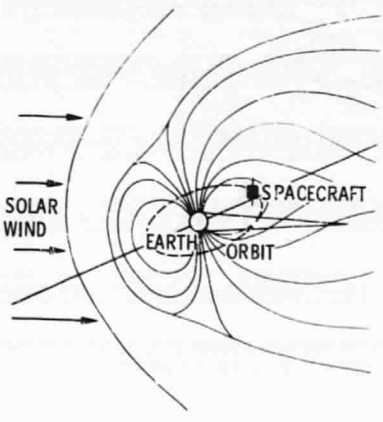
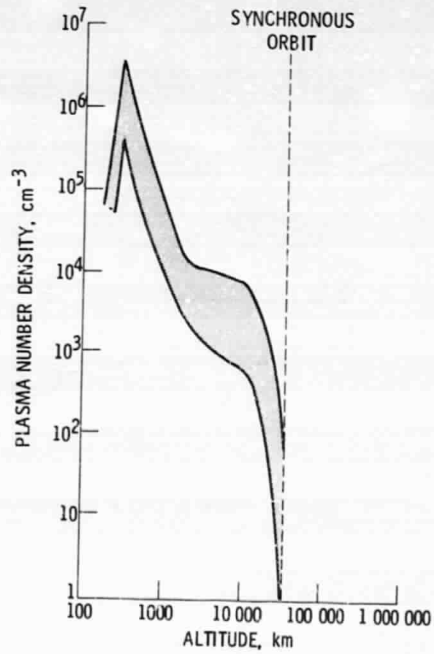


Figure 1. - Space Construction Facility (ref. 8).



(a) EARTH'S MAGNETOSPHERE.



(b) THERMAL PLASMA ENVIRONMENT.

Figure 2. - Earth's charged-particle environment.

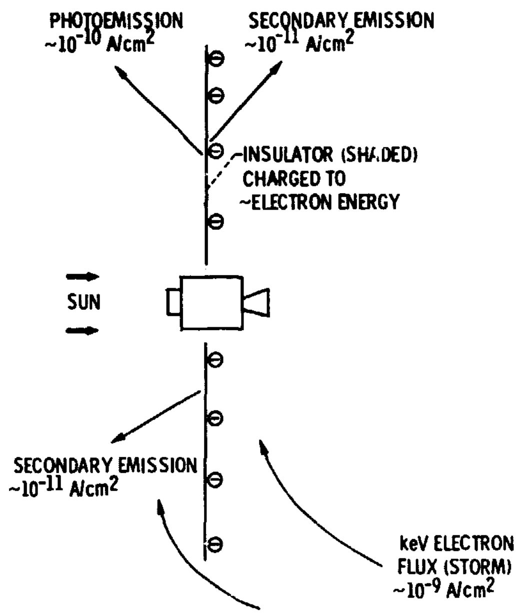


Figure 3. - Spacecraft charging interactions.

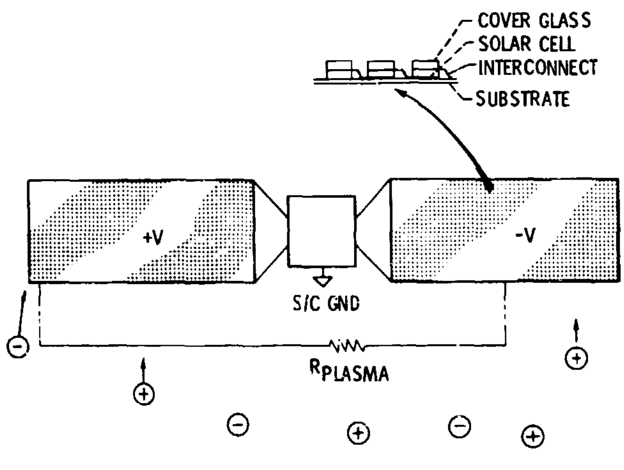
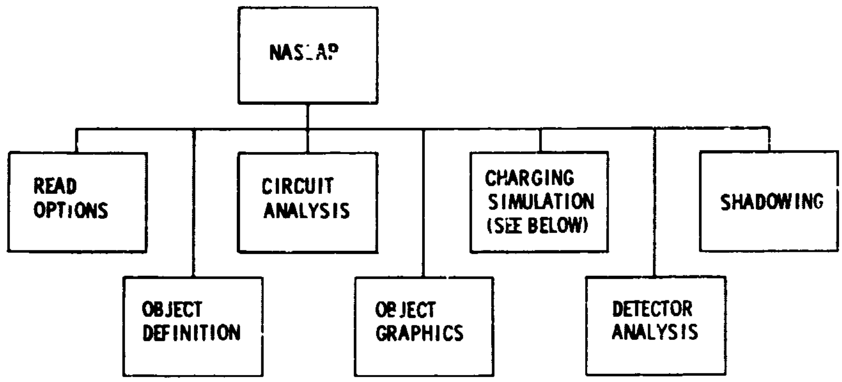
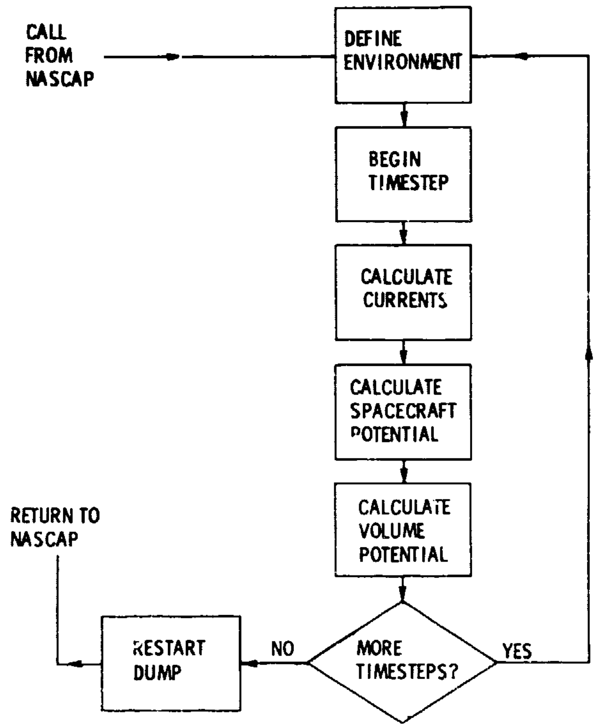


Figure 4. - Spacecraft higher voltage system-environment interactions.



(a) BLOCK DIAGRAM OF NASCAP CODE.



(b) FLOW DIAGRAM OF CHARGING SIMULATION.

Figure 5.

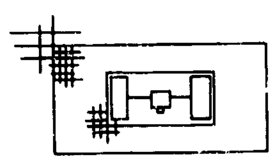


Figure 6. - Cross-section (y-z plane) of grid, showing first three embedded meshes.

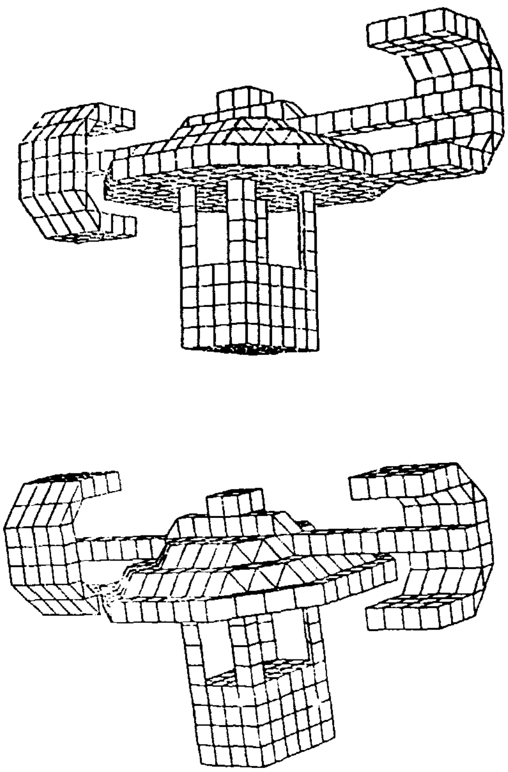


Figure 7. - NASCAP graphical output ATS-6 model.

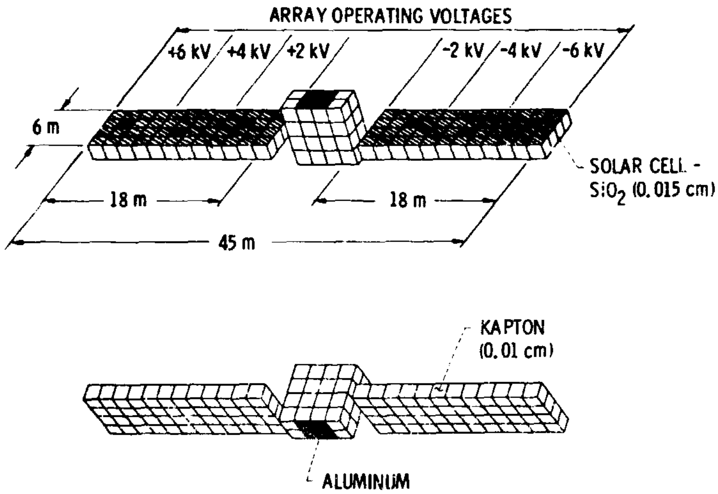


Figure 8. - NASCAP model high voltage system.

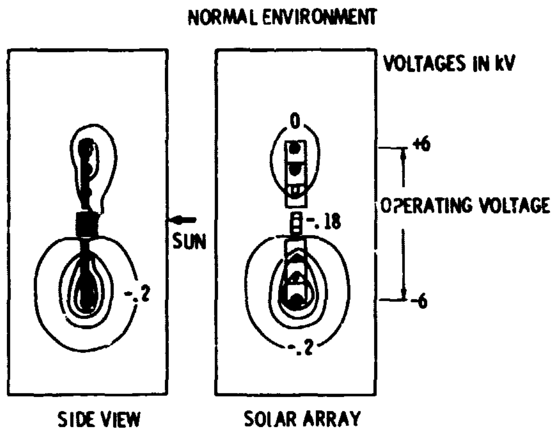


Figure 9. - High voltage system predicted voltage profiles.

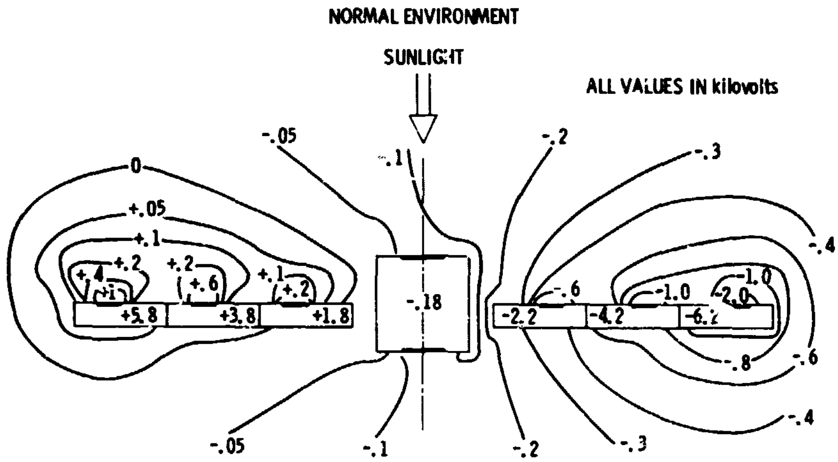


Figure 10. - Voltage profiles at biased surfaces.

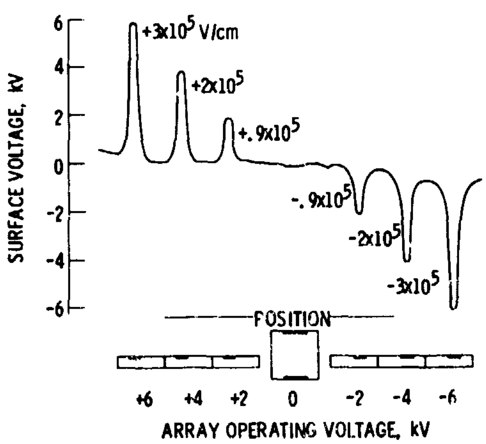


Figure 11. - Surface voltage across solar array.

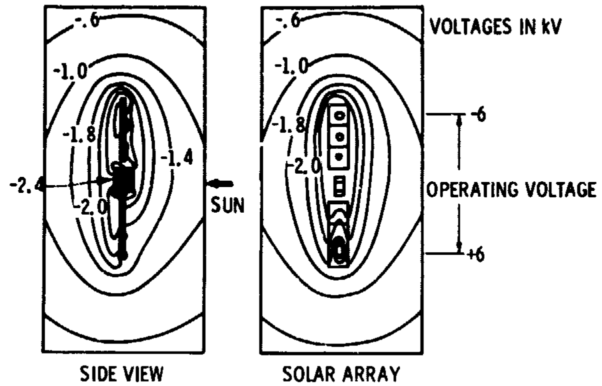


Figure 12. - High voltage system predicted voltage profiles. 5 keV substorm.

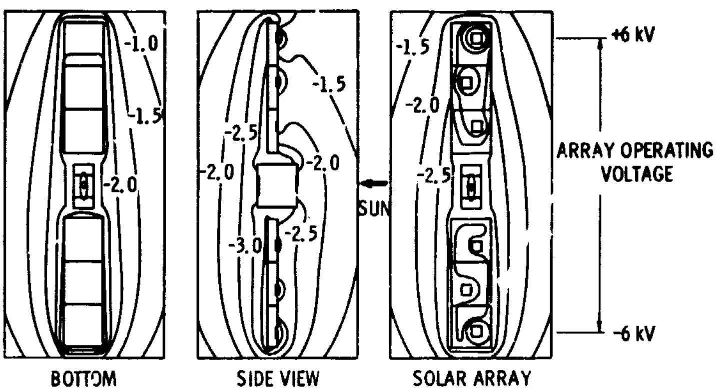


Figure 13. - High voltage system predicted voltage profiles - detailed. 5 keV substorm.

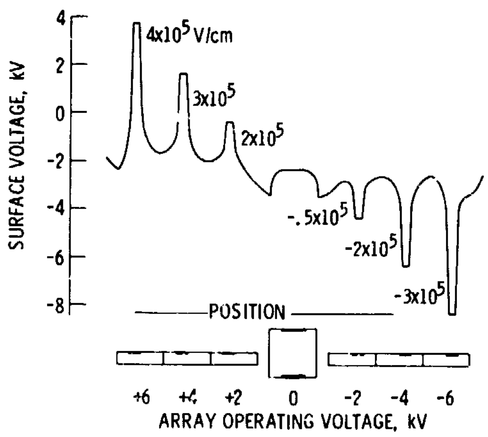


Figure 14. - Surface voltage across solar array. 5 keV substorm.

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15. Supplementary Notes

16. Abstract

One of the concerns with the proposed large space-power systems operating at high voltages is the interactions with the space charged-particle environments. These interactions can influence the performance of space power systems and should be evaluated and minimized early in design phases. An analytical tool that can be utilized to study these interactions exists. It is called NASCAP, an acronym standing for NASA Charging Analyzer Program. In this report the initial application to large, high-voltage space power systems is presented. A simple space power system operating in geosynchronous orbit is analyzed. This system consists of two solar array wings, each 6 m by 18 m, surrounding a central body 6×6×3 m. Each solar array wing is considered to be divided into 3 regions operating at 2000 volts. The center body is considered to be electrical ground with the array voltages both positive and negative relative to ground (±6 kV maximum). This system is analyzed for both a normal environment and for a moderate geomagnetic substorm environment. These initial results indicate a high probability of arcing at the interconnects on the negative operating voltage wing. There is also the possibility that the dielectric strength of the substrate can be exceeded (if the operating voltages are increased) giving rise to breakdown in the bulk of the material. The geomagnetic substorm does not seem to increase the electrical gradients at the interconnects on the negative operating voltage wing but does increase the gradients on the positive operating voltage wing which could result in increased coupling current losses.

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